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Contents

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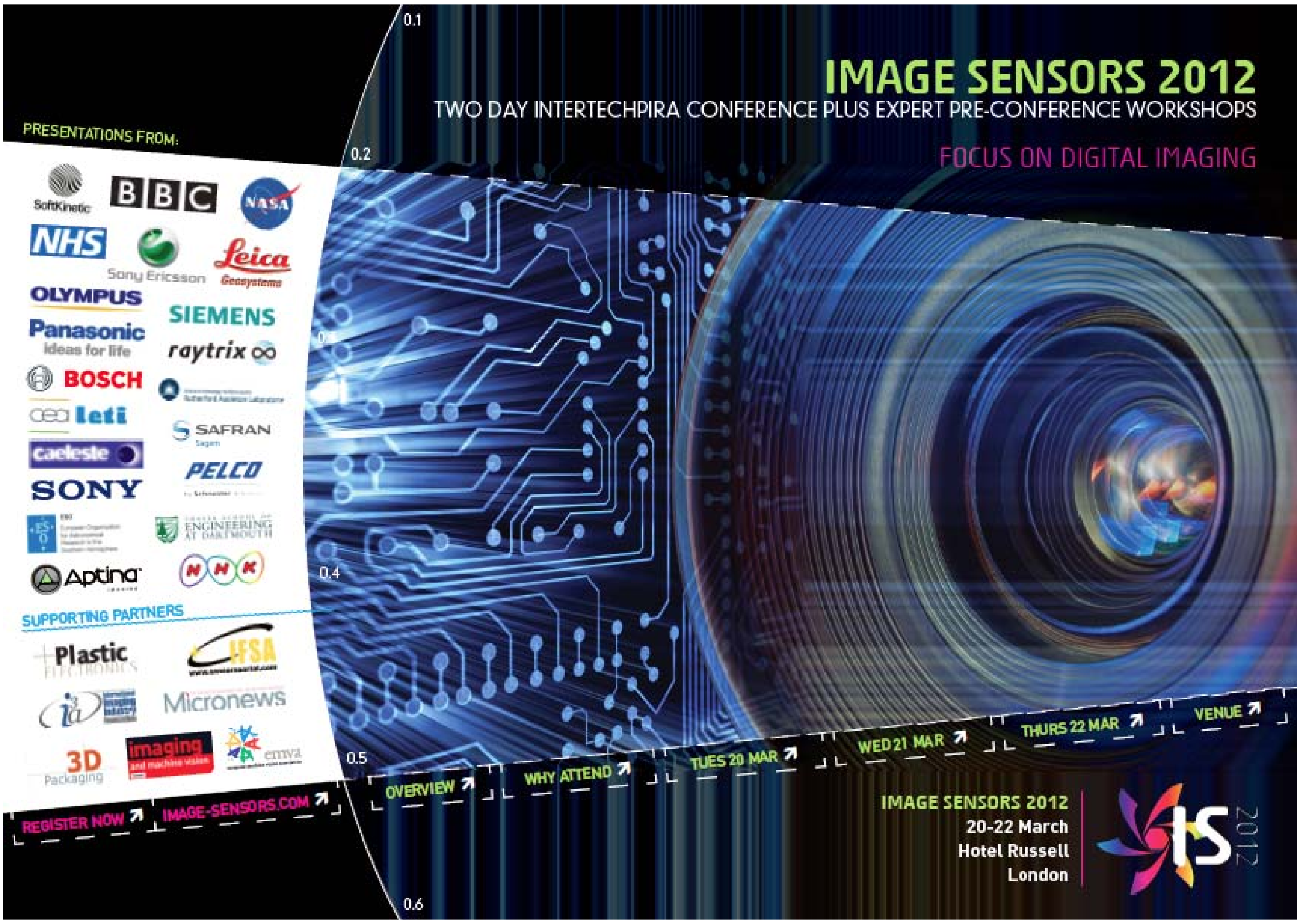

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Adapting OLSR for WSNs (iOLSR) Using Locally Increasing Intervals

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Abstract: Proactive link state routing protocols, popular within the Mobile Ad hoc NETwork framework, have not been as successful in wireless sensor networks. This is mainly due to the extensive energy usage by control traffic transmissions and state requirements. However, such protocols may in many situations be better suited than other routing schemes. The benefits are topology overview, and more importantly the availability of an optimized spanning tree for information distribution. The associated high signaling overhead can be reduced by taking advantage of the static nature of wireless sensor networks. In this paper, we investigate how the Optimized Link-State Routing (OLSR) protocol can be adapted to work better in a wireless sensor network environment by sending control messages with a low frequency when the network is stable, and more often if topology changes occur. The proposed solution is investigated using simulations from no loss to lossy link environments showing promising results. *Copyright © 2012 IFSA.*

Keywords: Ad hoc networks, Routing, Wireless sensor networks.

1. Introduction

Mobile Ad Hoc Networks (MANETs) and Wireless Sensor Networks (WSNs) are regarded as two distinctly different types of ad hoc networks, requiring routing protocols with specialized attributes. While MANET routing protocols are challenged with mobility, the main limitations for routing in

WSNs are energy and memory. The IETF 6LoWPAN (IPv6 over Low power Wireless Personal Area Networks) working group [1] have made great efforts to bring IP to WSNs and other low power wireless networks.

Radio communication is a major energy consumer in WSNs. In [2], it was measured that the energy consumption distribution of idle:receive:send was 1:1.05:1.4. From these numbers it is seen that idle listening and packet receival, even for packets addressed to other nodes, draws energy. Last, but not least, the major energy usage is due to packet transmission. Shwe et al. propose in [3] to minimize the number of control packet transmissions to reduce the energy usage. However, reducing the control traffic could make the routing protocols less capable of maintaining routes and manage route repair. Thus, our goal is to reduce the number of control packet transmissions while avoiding these negative consequences.

The traffic pattern types in WSNs are mainly the following, arranged in expected occurrence from high to low:

1. Sensors to sink;
2. Sink or a specific controller to all or some sensors;
3. Sensor to sensor.

In the first and third case, the main challenges that have been addressed are on optimizing energy preservation and memory usage. Recent work has been on propagating software elements to all or a group of sensors in a sensor network. The process of software updating would require a more optimized distribution tree. A proactive protocol enabling optimized message distribution and routing is an example of protocol synergies.

The Optimized Link State Routing (OLSR) protocol [4] is a proactive link state MANET routing protocol. It sets up and maintains routes regardless of application layer communication demands. The route maintenance is based on the regular transmission of control traffic. A high number of control packet transmissions will make the protocol less suitable for WSNs. At the same time it offers several advantages that are not as easily available with reactive protocols. For example, it can provide: quick rerouting in case of topology changes, spanning trees for information distribution, node cooperation, and node localization.

WSNs consist often of lossy links. In networks where links experience radio silence, a protocol enabling fast recovery is a requirement. Fast recovery enables higher network availability and provides more robustness. Proactive protocols enable fast recovery as they keep local link states, which are available upon link error. Although proactive protocols are less accurate in terms of link accuracy compared to their reactive counterpart, they have a reduced setup time and recovery time.

The OLSR protocol is specifically designed for dense node topologies, but not aimed towards static or failure prone environments. Due to its link state properties it also has a larger state requirement than other protocols tailored for WSNs. There are no specified mechanisms to adapt the emission intervals of control messages, depending on the grade of topology change or link failure. This means that the rate of control messages must be decided before the network deployment, based on the expected dynamics and the wanted reaction time to such dynamics. WSNs can be perceived as static and fixed without any dynamics. Nonetheless dynamics will occur, due to fluctuating links, new deployed nodes or nodes disappearing due to energy depletion or other malfunction. In a more dynamic network, where links or nodes break frequently, the routing protocol needs to perform control traffic dissemination more often.

The main contribution of this paper is the adaption of OLSR to exploit the static nature of WSNs through dynamically and locally increasing the intervals of the control messages. This proposed solution is named iOLSR. Scaling OLSR used in WSNs has been criticized for the extensive use of state, which makes scaling a challenge. However, for medium WSNs, the required memory for holding OLSR state will likely be below current memory limitations of many commercial nodes for WSNs. The proposed solution shows its ability to reduce its control traffic, and to deal well with environments experiencing error prone links.

The rest of the paper is structured as follows. Related work is presented in Section 2. The changes proposed to OLSR are presented in Section 3. The solution is investigated and compared to alternatives through simulations in Section 4. Finally, the paper is concluded in Section 5.

2. Related Work

Earlier work that address adaptation of OLSR for WSNs include [5], where Benslimane et al. propose a way to perform energy-aware routing using OLSR. Minet and Mahfoudh present an energy-aware version of the OLSR routing protocol in [6]. These two papers focus on routing traffic over paths that minimize the energy consumed in the end-to-end transmission of a packet flow and avoiding nodes with low residual energy, increasing the network lifetime. iOLSR, on the other hand, does not consider energy levels, but instead focuses on the reduction of control traffic.

The OLSR RFC [4] allows for different nodes having different interval settings, but there are no described options or methods to vary the intervals while operating. Fast-OLSR [7] is a proposal to enable the broadcast of Fast-Hello messages with a shorter interval in case high mobility is detected. It is thus a proposal to change the control message intervals with basis in information about the relative mobility of the node, depending on if there is a high number of changes in the node's neighborhood. In addition, Fast-OLSR proposes a Fast-Hello message with a reduced set of neighbors announced, to reduce the increased routing traffic overhead. Our proposed solution does not impose a new network message type and it is tested in link-error environments. iOLSR, contrary to Fast-OLSR, aims to increase the control packet interval. As with Fast-OLSR, iOLSR is compatible with the standard OLSR protocol.

An IPv6 routing protocol for Low Power and Lossy Networks (RPL) is currently being developed in the IETF. Clausen and Herberg investigate RPL-Enabled Optimized Broadcast in [8]. The authors argue that Multi-Point Relay (MPR)-based efficient broadcast is a well performing mechanism for WSNs, and the MPR mechanism is essential to the OLSR routing protocol, upon which we base our proposed solution.

Our research is inspired by other works that rely on adaptive beaconing. Several reliable data dissemination protocols for WSNs, including DIP [9] and Drip [10], are based on some variant of the Trickle algorithm [11]. Trickle exponentially increases its dissemination interval as long as all nodes agree on their summary data, and reports more quickly if a difference is detected.

The tree-based routing protocol CTP [12] uses adaptive beaconing by extending the Trickle algorithm to reduce the route repair latency and send fewer beacons when the network is stable. In CTP, the trickle timer interval is reset whenever a routing loop is detected or the routing cost decreases significantly.

3. Proposed Solution

The OLSR protocol uses two different control messages for its most basic routing functionality, *Hello* and *Topology Control (TC)*. The Hello messages are generated by all nodes and are periodically broadcasted to all 1-hop neighbors. Based on the information exchanged in Hello messages, a subset of the nodes in the network are selected as MPR nodes. These nodes generate TC messages, which are flooded throughout the network using the other MPR nodes.

The Hello and TC emission intervals affect the reaction latency to topology changes, and the intervals can be set balancing between the energy usage and the topology change discovery latency. The proposed default lengths of the Hello and TC intervals are 2 and 5 seconds, respectively, and the main motivation for these low values is the ability to cope with high mobility induced topology change.

There are two clear side effects of increasing the control packet intervals. The first is the increased latency in detecting link breaks. However, to reduce the link break detection time, disappearing nodes causing link failures can be detected using Link Layer Notification (LLN). The second side effect is the latency in detecting new nodes. If new nodes are introduced in the network when the network has been operating for a while, these nodes will only be employed for routing when the network has discovered them. However, until the new node has received TC messages from all elected MPRs in the network, there is a risk that the node will discard packets to destinations it is unaware of. And worse, generate loops if it has a different view of the shortest path than the upstream node. Large message intervals will delay the discovery and the use of more optimal paths.

In static WSNs, there are no topology changes caused by mobility. The topology is stable and static for most of the time. After performing the initial discovery of the topology, the routing protocol could stop disseminating control messages. However, at any time, a node may disappear or make its appearance in the network, and links may fluctuate. Links may even be broken due to external causes, such as targets entering the network detection zone and blocking radio signals, causing fading links. Therefore, even proactive protocols for WSNs must perform control with the network links to detect and recover from topology changes. To reduce the overhead of routing messages, which drains the nodes of energy, the message intervals can be increased or turned off. However, this is at the cost of slower detection of topology changes detected by necessary control packets.

We propose to allow each node to adjust its Hello and TC intervals depending on the local state of the network. In the initial startup phase, where each new received Hello message contains new information, the node keeps the default low interval between each new originated message. As the initialization phase draws to an end, and no more changes are experienced in the neighborhood, the control message intervals are increased. In this way, the energy usage is reduced while the topology is stable and unchanged. If a change is detected in the local neighborhood, the message intervals are reset, and then incremented anew when no changes are detected (i.e., this part of the network is perceived as stable again). The topology changes are detected by using Link Layer Notifications (LLNs) and through Hello messages containing new information. As a consequence, the protocol is able to adjust itself to operate over both stable links and more lossy environments while optimizing the overhead of routing messages through the increasing intervals.

The local interval reset process is best explained through Fig. 1, where traffic flows from the Source to the Sink through a number of relay nodes. Starting with a link failure between A and B marked by the red cross, the link failure is first detected by A through LLN. Node A resets its own Hello (and TC if selected as MPR) interval and then broadcasts a Hello message where B is now listed as a lost neighbor. This Hello message with new information is received by A’s neighbors, and these also reset their Hello and TC intervals. Node A calculates a new route to sink through either C or D. At a later time, node B will detect that the link to A is broken, due to timeout of the last Hello message received from A. B will then reset its own Hello and TC intervals and transmit a Hello message with new information, making the recipients of this message resetting their Hello and TC intervals. All nodes that are required to reset their Hello and TC intervals due to the link break between A and B are filled with grey.

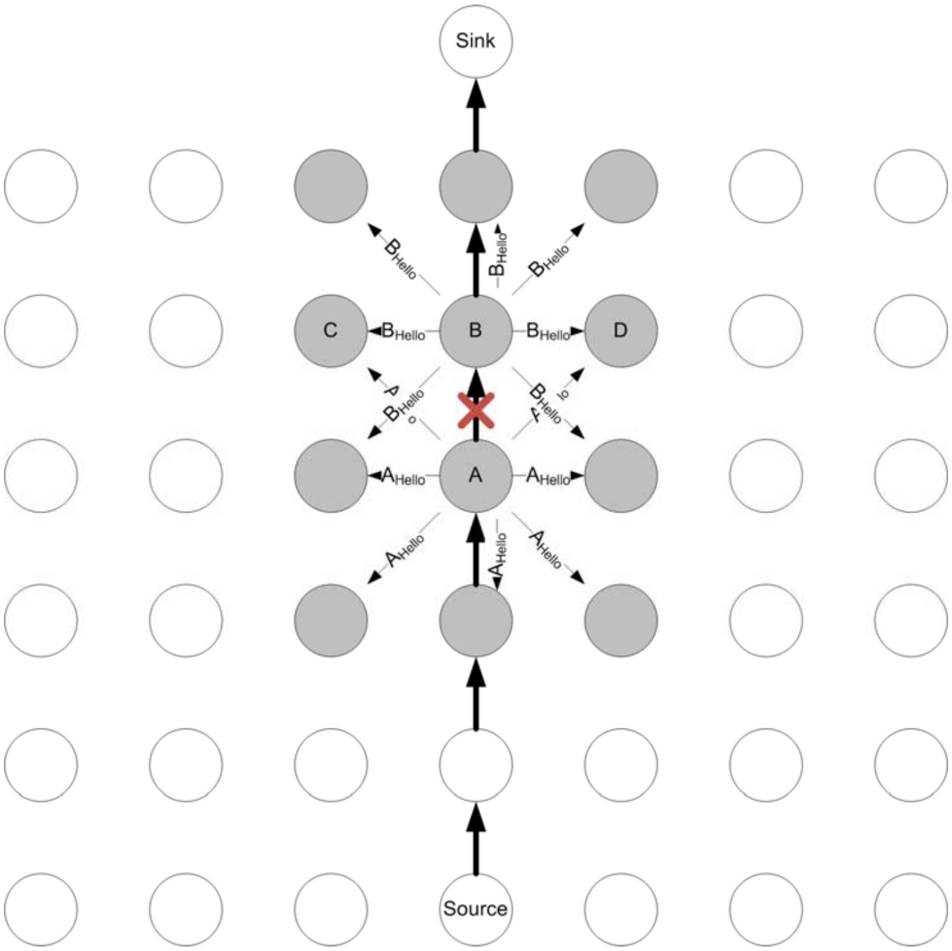

Fig. 1. The local reset of intervals.

In our proposal, the intervals of the control messages must vary between a lower and an upper limit. If the lower interval is too short, the number of control messages transmissions will drain the network nodes of energy without improving the routing protocol's reaction time. If set very low, collisions of control messages may even impair the network, causing data traffic packet loss due to lack of routes. In the upper end, the time fields of the OLSR message header limits the maximum interval. The time is encoded in the header in a mantissa and exponent format, each of 4 bits, into one byte. A time value i is encoded as

$$i = C \cdot \left(1 + \frac{a}{16}\right) \cdot 2^{b}, \tag{1}$$

where a is the highest 4 bits of the field, and b is the lowest 4. The scaling factor C is proposed as 1/16 second, giving a time field range of 0.0625 s - 3968 s. The scaling factor could be increased to achieve a higher maximum time range, which could be advantageous for our proposed solution, but this has not been looked into in this work. In such a case, one would lose the resolution at lower numbers.

The intervals and the corresponding message timeouts (valid times) are increased each time the control message is transmitted. Upon experiencing a change in the neighborhood the intervals are reset to the default values, and the incremental process begins over again. Depending on the fluctuations of the network, the optimal interval increase rate may vary. In the simulations, three different rates have been examined, and we have developed a generic representation of the calculation of control message intervals and their timeouts. The following formula represents the calculation of increasing the intervals continually, either linearly or exponentially. The generic interval v can be calculated as follows:

$$v = v_d \cdot \left(\alpha^i + \beta \cdot i\right) \tag{2}$$

In (2), v is the resulting interval, v_d is the starting (default) interval, α is the base exponential value, β is the linear increment and i is a counter of successfully transmitted control messages. Upon a change in the local topology information, this counter is reset to 0.

The basis for message information timeout has been to follow the proposal of the OLSR RFC [4], using 3 times the interval rate as the timeout value. However, with an expected increasing interval, the timeout vt must be calculated as stated in (3).

$$vt = \sum_{k=0}^{2} v_d \cdot \left(\alpha^{(i+k)} + \beta \cdot (i+k)\right) \tag{3}$$

In the equations, α and β are constants, set for the entire duration of the simulation use or network deployment.

4. Simulations

4.1. Setup

The proposed solution was investigated using simulations on the ns-2 network simulator [13] version 2.34. The OLSR protocol as described in [4] and implemented for ns-2 in [14] was used for unicast routing, and the IEEE 802.11 protocol [15] was used as MAC layer. LLN was enabled in all simulations.

The solution was tested on a scenario with fluctuating links where the link loss is a consequence of link failures using an implementation of the Gilbert-Elliot link burst error model [16, 17]. The link has a certain probability of going into a 0-3 s burst error period, and while in the burst error period, the link experiences a 100 % packet loss. When not in a burst error period, the two-ray-ground radio propagation model is employed with a 250 m transmission radius. The decision of whether a link is in a burst error period or not is taken as follows: Beginning at t=0 s, a random time t_r between 0 and 3 s in the future is drawn. Along with t_r, the link's error state is decided through drawing a random value between 0 and 1 and comparing this with the selected probability of entering a link burst error period. The selected state is then valid until the time has become t_r. At this time, a new t_r and a new link state is drawn.

The topology size was set to 40 nodes in a 1500 × 300 m^2 area. The nodes were placed randomly using software from [18], to allow the examination of a wide network without the very long simulation processing time that follows using ns-2 with a high number of simulated nodes. The sink was randomly positioned. The simulation time was 6000 seconds unless otherwise stated. All nodes generated packets, except those nodes that appeared or disappeared, and the packets were set with the sink as destination, to test the paths toward the sink. The traffic load was 1 packet per second from each traffic-generating node. The traffic type was UDP unicast with a packet size of 50 bytes, and the traffic flows were started at 500 s. All data points are an average of 10 simulation runs, and are presented with a 95 % confidence interval. The topologies were the same 10 topologies for each of the simulations. Other simulation parameter settings are presented in Table 1.

Table 1. Simulation parameter settings.

Radio-propagation model	TwoRayGround
Interface queue type	FIFO with DropTail, PriQueue for OLSR packets
Interface queue size	30 packets
Antenna Model	OmniAntenna
Data/basic rate	2 Mbps / 1 Mbps
Data transmission/sensing radius	250 m / 550 m
Simulation/measurement time	6000 s / 600-5900 s
Random seed	Heuristic
Traffic TTL	32

For our proposed iOLSR solution, the interval incrementation counters were reset at the following events:

- Hello messaging causing link change or timeout.
- A new MPR selector or a timeout of an existing one.
- Link break causing a LLN.

When the static Hello intervals were increased, the TC intervals were increased correspondingly, so that for example a Hello interval of 10 had a TC interval of 25.

4.2. Results

4.2.1. Increasing Intervals

First, we compare iOLSR and its dynamic interval solution to the regular static interval behavior of OLSR in varying link stability conditions. Three different static Hello intervals were simulated: 2, 20 and 100 s. The corresponding TC intervals are: 5, 50 and 250 s. The iOLSR default intervals were 2 s for Hello and 5 s for TC, and the interval increment was 2-base exponential ($\alpha = 2$ and $\beta = 0$). Examining the goodput results (Fig. 2) we see that all the configuration variations manage to perform well when the topology is stable without many link errors. When the link error probability increases, a higher interval between the Hello messages makes the routing protocol less capable of taking advantage of the links recovering from a burst error, and this leads to a logical partitioning that reduces the goodput. Interestingly, we mark that iOLSR is able to offer the same performance as that of standard OLSR with 2 s Hello intervals, even at the highest link burst error probability.

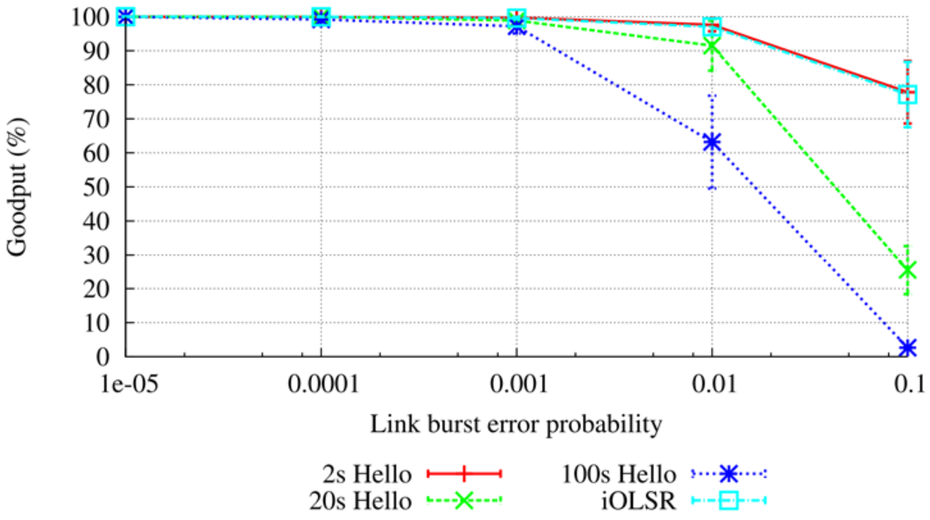

Fig. 2. Average goodput for iOLSR compared to OLSR with static intervals.

While the goodput performance for all alternatives was very good at the lower link break probabilities, it is the number of transmitted control packets that is most interesting in WSNs, since the number of transmissions directly affect the energy use of the nodes. Hence, the energy is preserved by reducing the path-length and the total number of control packets. The number of control packet transmissions (Fig. 3) show iOLSR as being highly adaptive to the environment it operates in. When there is low probability of burst errors, the number of routing packets is kept at a much lower level than the comparable 2 s Hello interval results, and even compared to the 100 s Hello results. As the burst error probability increases, the routing protocol dynamically increases the number of Hello and TC messages generated locally in the area around each failing link.

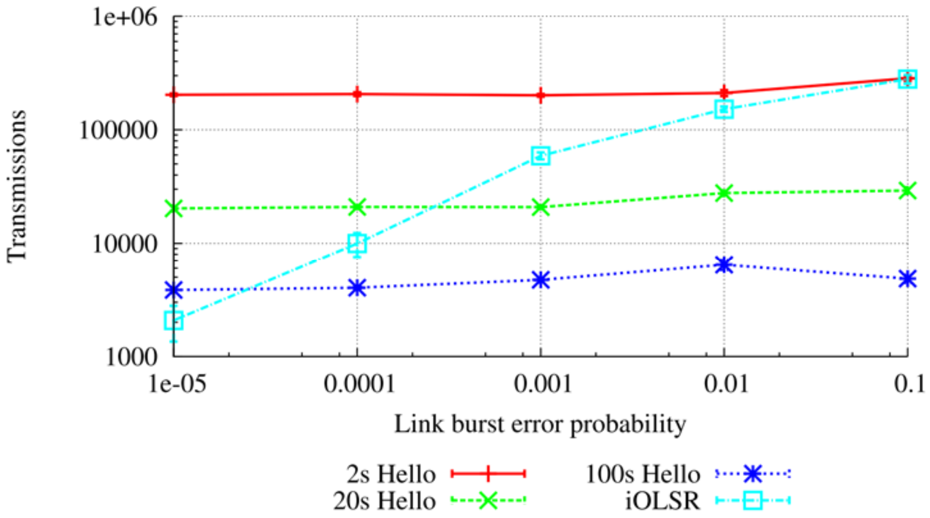

Fig. 3. Number of control packet transmissions for iOLSR compared to OLSR with static intervals.

The number of lost packets due to no-route to the destination (Fig. 4) is a consequence of one or more transient link errors preventing control packets of reaching the entire network. Consequently, the network becomes partitioned. As the link fluctuation increases, the number of packets lost also increases. It is evident that the 100 s and 20 s Hello interval results yield worse performance compared to the 2 s Hello and iOLSR with 2 s default Hello interval, and the 100 s Hello interval is worse than the others overall. The reason is the already mentioned problem of partitioning, because of failure to detect links that were down earlier due to link burst error, as well as links coming up again.

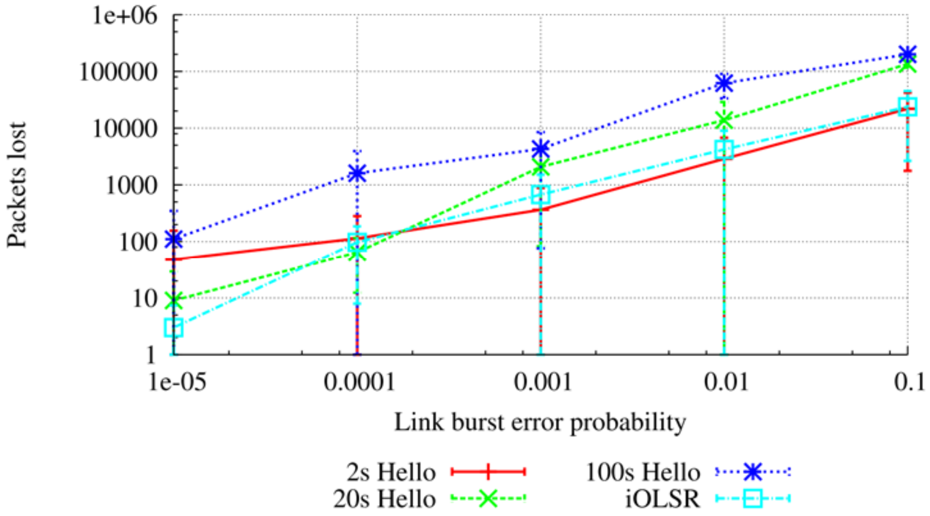

Fig. 4. Packet loss caused by lack of route for iOLSR compared to OLSR with static intervals.

4.2.2. Interval Increment Rate

The control message intervals' rate of increase is important when evaluating iOLSR. We have investigated three increment options where α and β refer to (2) and (3):

1. Linear (lin) ($\alpha = 1$ and $\beta = 1$)
2. 2-base exponential (exp2) ($\alpha = 2$ and $\beta = 0$)
3. 3-base exponential (exp3) ($\alpha = 3$ and $\beta = 0$)

As we see in Table 2, the linear option will increase the interval by the default value for each successful transmission, while the 2-base and 3-base exponential options increment the message intervals exponentially according to (2).

Table 2. Control message interval progression.

Hello			TC			
Lin	**Exp2**	**Exp3**	**Lin**	**Exp2**	**Exp3**	**Exp3 vt**
2	2	2	5	5	5	65
4	4	6	10	10	15	195
6	8	18	15	20	45	585
8	16	54	30	40	135	1755
10	*32*	*162*	*35*	*80*	*405*	*5265*
12	*64*	*486*	*40*	*160*	*1215*	*15795*
14	*128*	*1458*	*45*	*320*	*3645*	*47385*
…	…	…	…	…	…	…

The simulation results with varying control message interval incrementation rate show that the goodput (Fig. 5) is not affected adversely by choosing neither a 2-base nor 3-base exponential increase of the intervals, even in an environment with a high probability of link burst errors. It follows the linear increment results very closely.

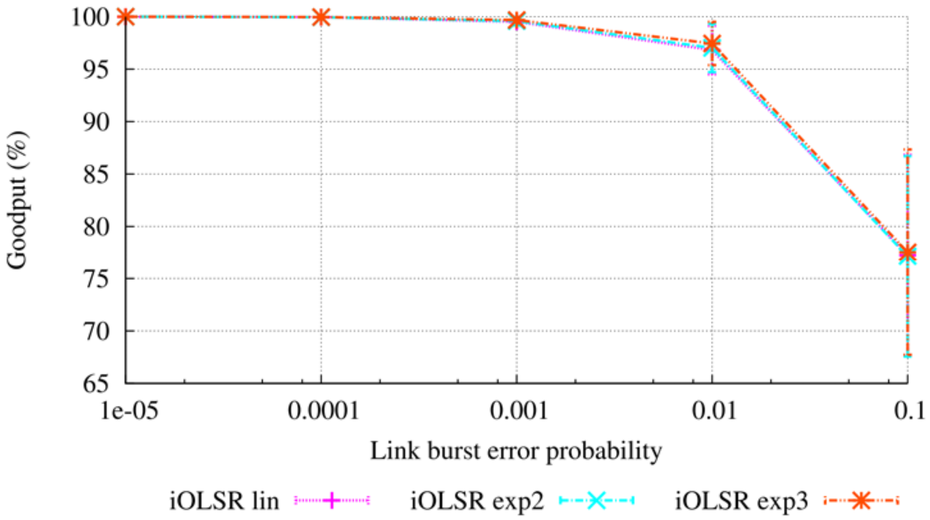

Fig. 5. Average goodput for linear contra exponential increase of iOLSR intervals.

Examining the results for the number of control packet transmissions (Fig. 6), there is evidently great gain in using an exponential interval increment compared to a linear increment. However, the gain is much less in using a larger base exponent such as 3 compared to 2. The reason is twofold. First, the number of transmissions required to reach the maximum time field limit is lower with an increasing increment. After the incrementation phase, there is no difference between the increment values, since the intervals are no longer increased. For the exp3, the maximum interval for TC is reached at the fifth transmission, since the vt (control message information timeout) will be 5265 (Table 2), thus exceeding the maximum time (3968). Second, the beginning of the incrementation phase is the phase where changes are most likely to happen, especially at the initialization of the network. An interval increment that moves too quickly towards higher control message intervals may actually harm the initialization and convergence of the protocol, due to a prolonged initialization phase.

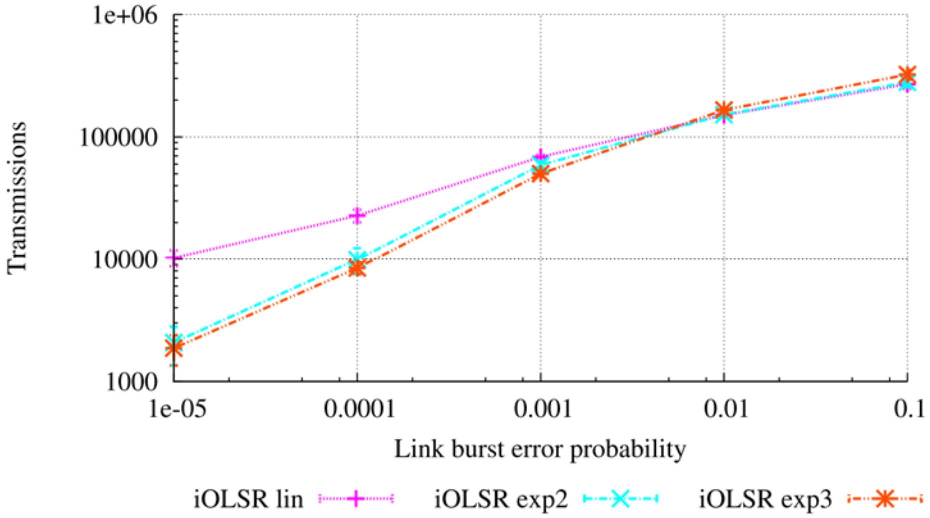

Fig. 6. Number of control packet transmissions for linear contra exponential increase of iOLSR intervals.

Since there is great impact of the initialization phase length, when it comes to the number of transmissions, we have run some simulations with only routing traffic present (without data traffic). The number of control packet transmissions is examined for the lin, exp2 and exp3 increment options. For a simulation lasting for 300000 s (Fig. 7), clearly the lin option is unable to reach the maximum interval. The two other options, however, reach the maximum interval after the first step.

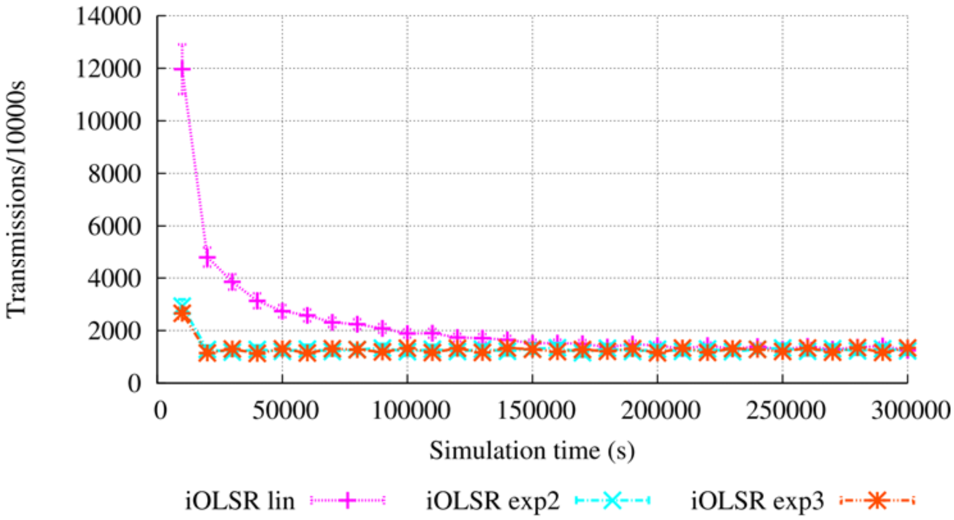

Fig. 7. Number of control packet transmissions for linear contra exponential increase of iOLSR intervals at increasing simulation time, 0-300000 s.

The conclusion of the investigation into the increment alternatives is thus that there is no significant difference between the 2-base and 3-base exponential increment, but both represent a significantly lower number of transmissions compared with the linear increment.

4.2.3. Comparison with AODV

The final comparison in this paper is between the iOLSR (2-base exponential increase) and Ad hoc On-demand Distance Vector (AODV) [19]. Several protocols that are based on AODV have been proposed as routing protocols for WSNs. These include AODVjr [20], TinyHop [21], LOAD [22] and DYMO-Low [23], which all implement different subsets of the AODV routing protocol. Due to its sink-oriented focus, many protocols for WSNs establish routes from sink to sensors to reduce the control traffic. However, AODV and its WSN-siblings establish routes from sensors to sink, and introducing unnecessary control traffic, due to the flooding of route requests originating in each and every sensor node. In this work we want to compare the impact of burst error on iOLSR to a reactive protocol handling path/link recovery, such as AODV. In lack of a more WSN-oriented routing protocol, we still choose to compare iOLSR with AODV, due to the many proposed adaptions of AODV for WSN.

With AODV, the starts of the traffic flows were spaced with 1 second intervals, to prevent the effect of RREQ synchronization in the route setup process. AODV was run with all the default ns-2.34 parameter settings. In particular, Local Repair and LLN was enabled. The goodput results (Fig. 8) show the interesting fact that AODV and iOLSR follow each other closely until a link burst error probability of 0.01. As the burst error reaches 01, AODV is better than OLSR at sustaining the goodput, although at the cost of the total number of transmissions. This is addressed later on in the paper.

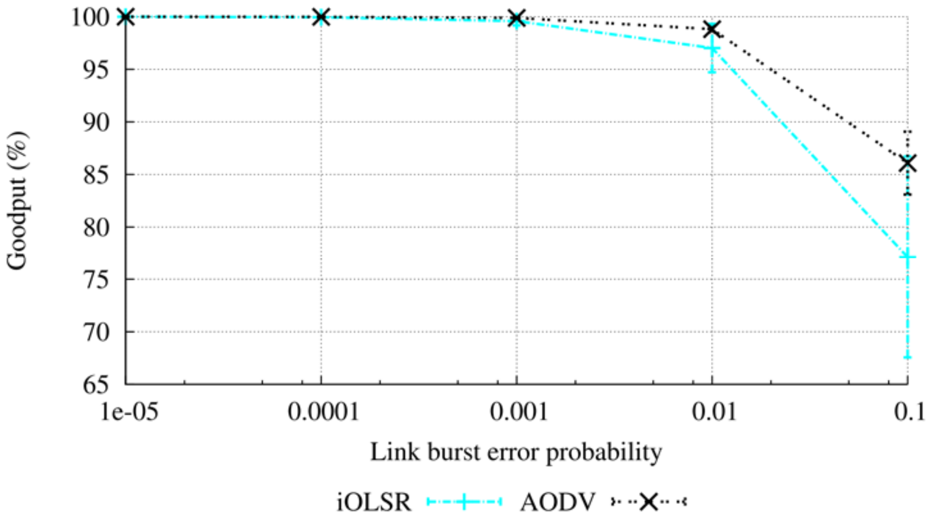

Fig. 8. Average goodput for iOLSR contra AODV.

Examining only the number of control packets transmitted (Fig. 9) with the goodput results in mind, at a low grade of link errors AODV obtains similar goodput to that of iOLSR, but with a reduced number of control messages. At a high grade of link errors, AODV achieves higher goodput than iOLSR at the cost of an increased number of control messages. The results are expected to be a consequence of the difference in link accuracy. AODV establishes routes on demand, and hence has a more recent link state than proactive protocols. AODV is able to detect new links faster than the minimum interval of iOLSR, which is in the range of 2 to 4 seconds due to the bidirectional detection requirement. Route error as a consequence of iOLSR control interval is illustrated in Fig. 4. Ideally, iOLSR should operate in the range 0.0625 - 3968 s given by mantissa in (1) at the cost of increased overhead. Also, AODV ensures consistent routes throughout the network, while iOLSR has to rely on the TC interval as well to allow all nodes to discover the new valid paths. This is also shown through the difference in the number of packets lost because of no route to the destination (Fig. 10).

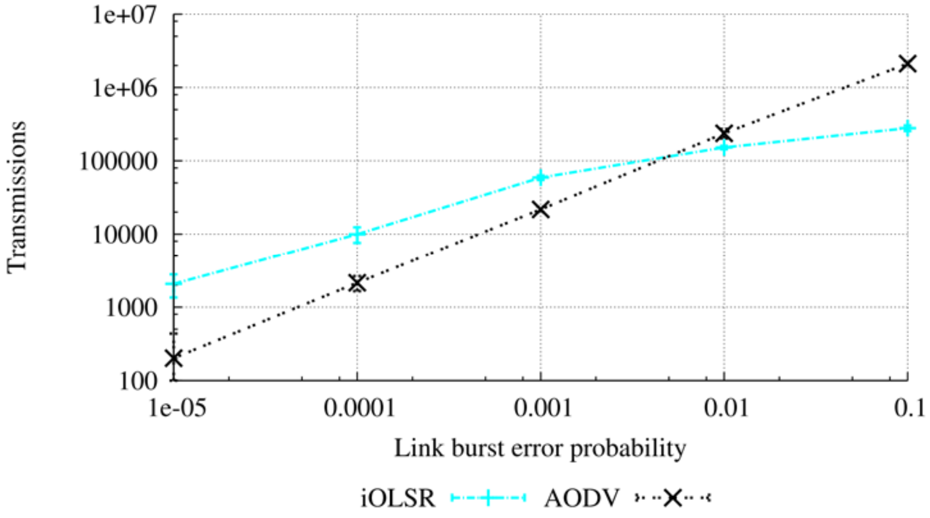

Fig. 9. Number of control packet transmissions for iOLSR contra AODV.

However, the control packet results only tell part of the story. Investigating further, the number of hops for the data traffic (Fig. 11) is much higher for AODV than for iOLSR. Although the total number of control packets may be low, the forwarding transmissions of the route requests are at risk of collisions. Control packet collisions might result in a failure to propagate the shortest, most optimal, path outwards to the destination, and hinder the establishment of routes to more distance nodes.

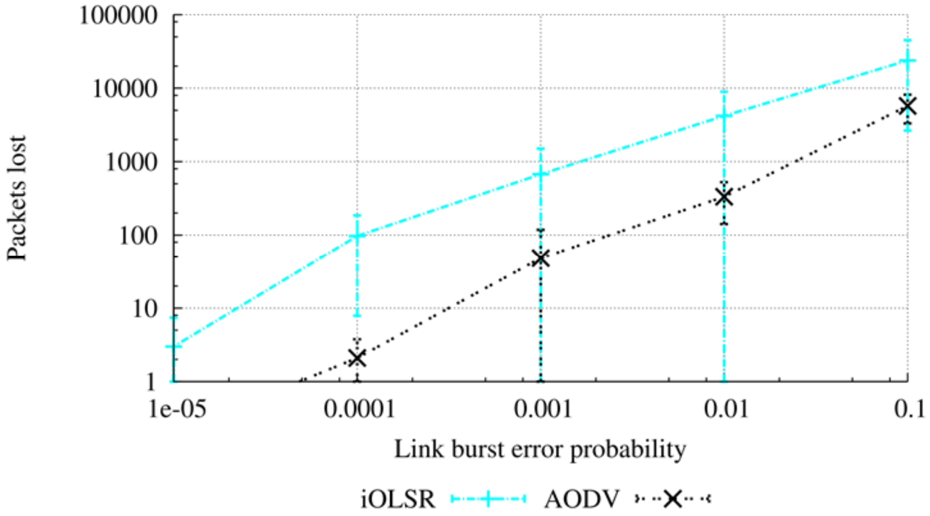

Fig. 10. Number of packets lost due to lack of route to the destination for iOLSR contra AODV.

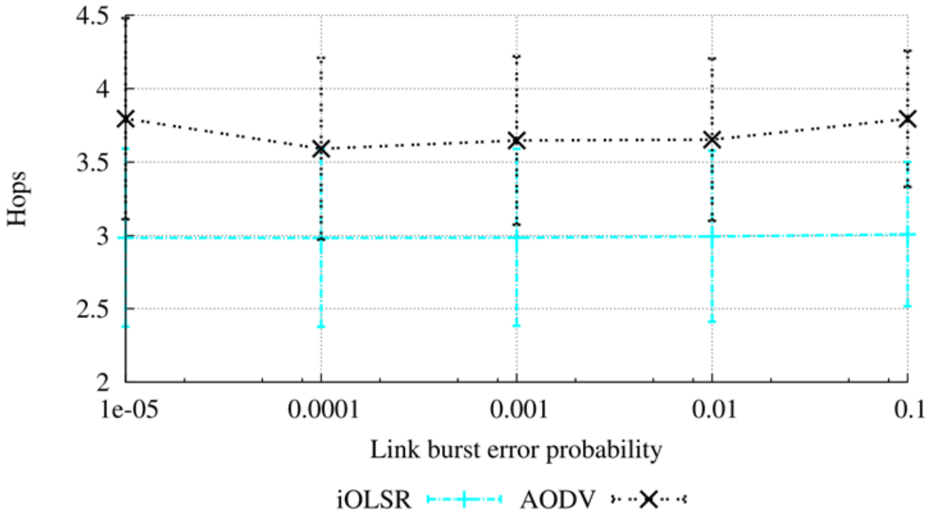

Fig. 11. Average number of hops for the data traffic for iOLSR contra AODV.

The consequence of the higher number of hops for the data traffic using AODV is the higher total number of transmissions (Fig. 12) where both the data traffic and control traffic transmissions are counted.

AODV and iOLSR experience different end-to-end hop count as a consequence of two protocol differences: path calculation and vulnerability to lost control messages. AODV is a reactive protocol. It basically works by the source initiating route discovery if no corresponding route entry is found. That is, a route is established based on the current link status from source to destination. Contrary, iOLSR regularly exchange link information with a predefined validity time. A route is therefore established based on the current status of the link repository and not the network link status. A consequence of a long link validity time is that the majority of the links are presented in the link repository independently of their current status. Consequently, iOLSR tends to calculate shorter end-to-end paths than AODV, although iOLSR has reduced path accuracy. Reduced path accuracy is however mitigated by intermediate nodes enabling local rerouting. AODV is also more vulnerable to establishing a longer path than proactive protocols, due to its vulnerability to lost control messages. A lost control message over an intermediate node on the shortest path results in added path length. Networks with high link error will initiate more control packets leading to a higher traffic load, which again increases the probability of packet collision. iOLSR uses an optimized spanning tree for dissemination of control messages. This spanning tree is designed for reduced packet redundancy. Hence, iOLSR is more vulnerable to establishing routes to more distant destinations than AODV utilizing network flooding.

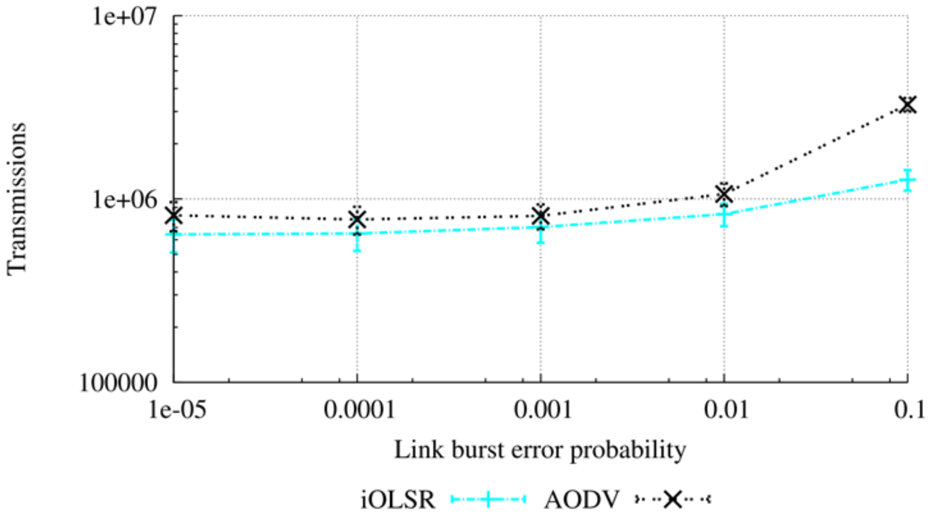

Fig. 12. Total number of transmissions (control and data traffic) for iOLSR contra AODV.

5. Conclusions

This paper has presented an adaptation of OLSR for WSNs by introducing dynamically adaptive intervals. The advantages of employing dynamic intervals for control packets were demonstrated. We achieved less control packet overhead than by using the default control packet interval. Also, we demonstrated a faster detection and integration of new nodes than by using a large control packet interval.

The solution induces costs in terms of less route maintenance. Even so, the proposed solution represents a much better alternative for reducing the number of transmissions than that of preset large intervals, since it will depend on the real dynamics of the network whether the routing protocol transmits many or few packets. Last, but not least, using a proactive protocol enables a more optimized traffic pattern from sink to sensors.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

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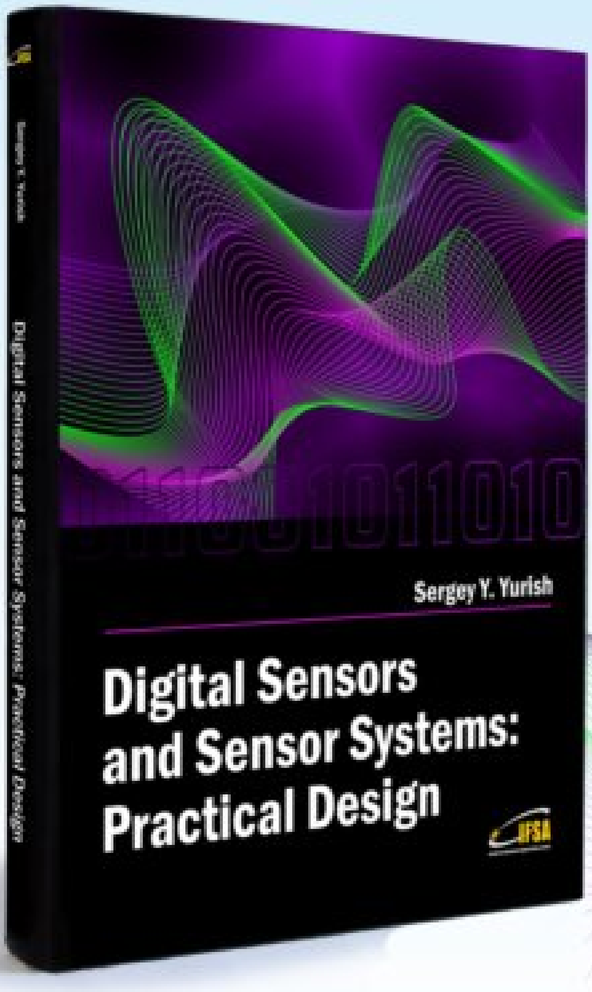
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